Final Report
Iowa Highway Research Board
HR-294

AMMONIUM PHOSPHATE/FLY ASH ROAD BASE CONSTRUCTION

By

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Performed in cooperation with the Story County Secondary Road Department and Iowa State University

8. ABSTRACT

The objective of this research project was to evaluate the construction and service performance of ammonium phosphate/fly ash (APFA) treated base courses of crushed fines and/or unprocessed sand. Specific test results related to construction of the test sections were included in the 1987 construction report by Iowa State University. The performance of the experimental sections is dealt with in this final report.

This 1986 project demonstrated that in all cases the control sections utilizing a Type B base experienced dramatically less cracking in the surface than the APFA treated base sections. The cost per mix and subsequent surface maintenance costs for the APFA base sections, especially those having a substantial amount of limestone, were higher than the Type B base control sections. This type of construction may prove to be economical only when petroleum product costs escalate.

9. KEY WORDS	10. NO. OF PAGES
Base Stabilization, Rigid Base, Ammonium Phosphate, Fly Ash	24

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DISCLAIMER

The contents of this report reflect the views of the author and do not necessarily reflect the official views of the Iowa Department of Transportation. This report does not constitute any standard, specification or regulation.

ABSTRACT OF CONSTRUCTION REPORT

This research project was initiated by Iowa State University under the direction of Dr. John Pitt in 1986. Preliminary laboratory work suggested that an ammonium phosphate/fly ash (APFA) base could be up to three times more effective than cement-treated base courses. This was based on cost compared to realized strength. The objective of the research was to evaluate the construction and service performance of APFA treated base courses of crushed fines and/or unprocessed sand.

Based on the construction report, the following observations and conclusions were offered:

1. The concept was workable and the end product appeared to be able to provide a satisfactory base.

2. The plant used to mix the aggregate-fly ash mixture should have adequate means for controlling the mix ingredients to a close tolerance.

3. When dry ammonium phosphate is used to retard set, the solution containing the ammonium phosphate must hold it in suspension. Air agitation was most adequate. Use of liquid ammonium phosphate could lessen the suspension problem but the cost could be prohibitive.

4. The mixes could be placed with good uniform thickness with a slipform paver. Also, a full width paver should provide more satisfactory placement and a better surface.

INTRODUCTION

A forerunner to this project was Iowa DOT project HR-225, "Characterization of Fly Ash for Use in Concrete," which indicated that small amounts of inexpensive compounds could be used to control set and enhance the strength of fast setting, self-cementing fly ashes. Further research from Iowa DOT project HR-260, "Optimization of Soil Stabilization With Type C Fly Ash," indicated that fertilizer grade ammonium phosphate produced strength increases of up to five-fold for some fly ashes, and increased set time from a few minutes to more than an hour. The intended result continues to be achievement of a low-cost yet strong base stabilizer suited for areas where kiln dust, lime and portland cement are too expensive to transport.

OBJECTIVE

The objective of this research project was to evaluate the construction and service performance of ammonium phosphate/fly ash treated base courses of crushed fines and/or unprocessed sand.

PROJECT LOCATION AND DESCRIPTION

A 2.9 km (1.8 mile) granular surfaced extension of R63 in Story County was selected for this project (Figure 1). Based on the 1983 average daily traffic of 250 vehicles, a fly ash stabilized base of 152 mm (6 in.) and a 38 mm (1.5 in.) asphalt cement concrete surface would be adequate. The 1991 average daily traffic was 500 vehicles per day, double that of the year 1983.

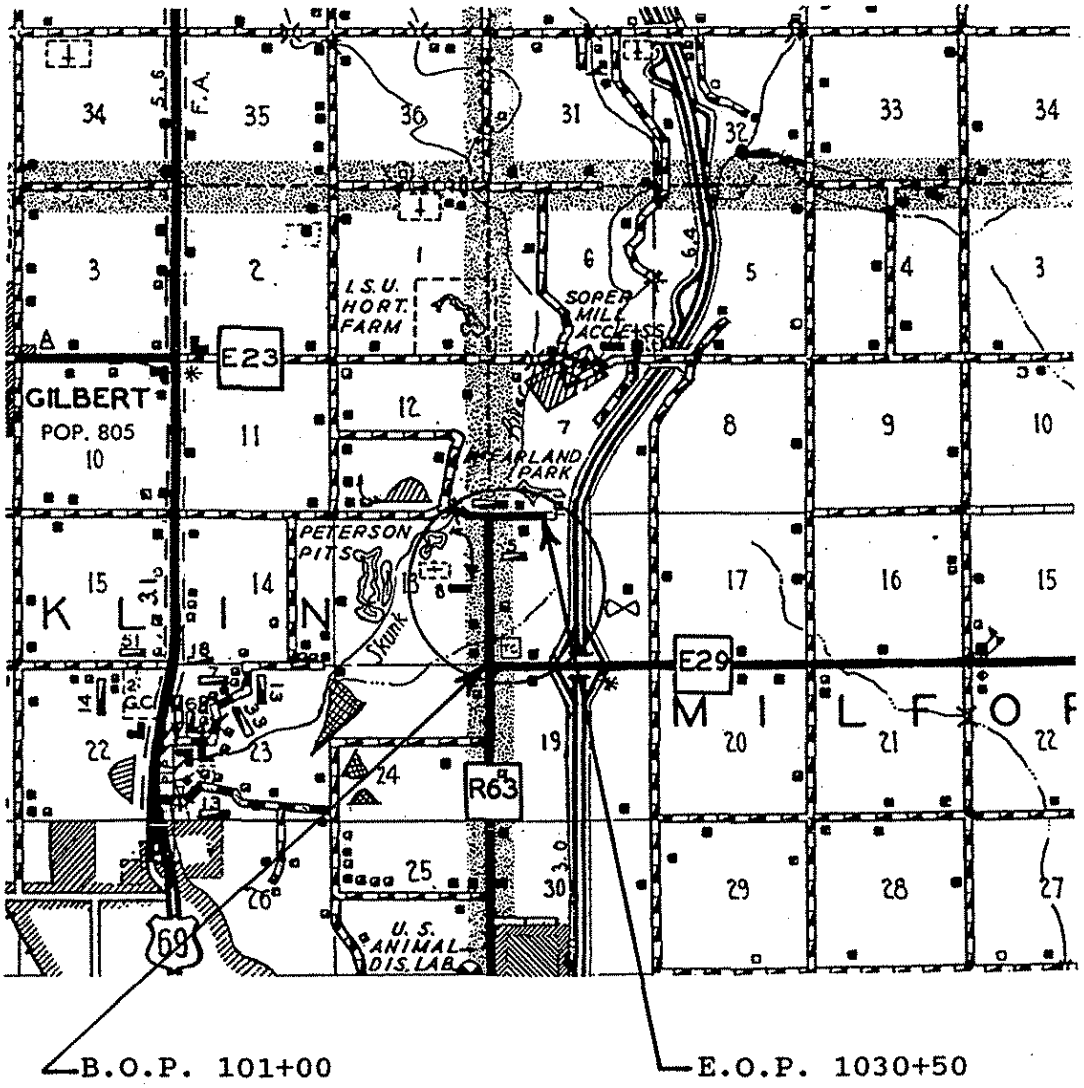


Figure 1

CONSTRUCTION

The project was constructed from August 18, 1986 through October 7, 1986. Des Moines Asphalt & Paving Company was the prime contractor. Manatt's Incorporated of Brooklyn, Iowa was the subcontractor that constructed the fly ash base sections. Special provisions are given in Appendix B. The layout of the experimental sections are shown in Table I.

Four different research sections consisting of 152 mm (6 in.) and 203 mm (8 in.) thicknesses of ammonium phosphate fly ash base with either a seal coat or a nominal 38 mm (1.5 in.) thickness of hot mix asphalt concrete were proposed. Mix designs incorporating 10 mm (⅜ in) crusher fines and natural sand along with 30% fly ash and 1.5% ammonium phosphate were considered (Tables II).

(Wearing Course)			
Sta. to Sta.	Depth	Lifts	Material
101+00 152+18	1.5"	1	Type B Surface
989+00 1030+50	1.5"	1	Type B Surface
(Base Course)			
101+00 107+00	4.5"	2	Type B Base
107+00 109+00	4.5"-6"	1	Type B Base
109+00 114+00	6"-8"	1	Modified Mix No. 3
114+00 128+40	7"-9"	1	Modified Mix No. 3
128+40 132+00	7"-8"	1	Mix No. 1
132+00 138+00	4.5"-7"	2	Type B Base
138+00 152+18	4.5"	2	Type B Base
989+00 1000+00	4.5"	2	Type B Base
1000+00 1014+70	6"-8"	1	Type B Base
1014+70 1017+00	8"	1	Mix No. 3
1017+00 1022+00	8"	1	Mix No. 3
1022+00 1030+50	6"	1	Mix No. 3

Table I - Placement Tabulation

Mix Type	Material	Weight (lb)
Limestone Base (Mix No. 1)	⅜" minus Limestone	1517
	Fly Ash	303
	Ammonium Phosphate	4.5
	Water	180
Sand and Limestone Base (Mix No. 3)	⅜" minus Limestone	582
	Sand	1106
	Fly Ash	303
	Ammonium Phosphate	4.5
	Water	180
Mod. Sand and Limestone Base (Mod. Mix No. 3)	⅜" minus Limestone	1225
	Sand	305
	Fly Ash	305
	Ammonium Lignosulfonate	3.05
	Water	165

Table II - Fly Ash Base Mixes

The base mixture was produced through a pugmill and placed through two asphalt pavers. The base material was compacted with a double drum vibratory roller, which at times produced tension

cracks before the base set. After two days, rapid initial setting resulted in hardening of the mix in the truck prior to delivery of the material to the asphalt paver. The specific cause of this problem was the ammonium phosphate settling out of the concentrate and becoming too dilute to extend the initial set. The county agreed to include ammonium lignosulfonate as a retarder/strength enhancer to combat this problem. In addition, better agitation of the ammonium phosphate helped to keep it suspended in solution longer. Due to substantial undulation of all the test sections, an asphalt concrete overlay was used on all of the experimental test sections and the use of a seal coat surface was deleted.

ROAD RATER SUMMARY

Road Rater™ testing has been conducted annually over selected research sections. The Road Rater is a dynamic deflection measuring device used to determine the structural adequacy of pavements. The difference in pavement structural ratings from year to year may be explained by the fact that annual testing is performed in the outside wheeltrack during the months of April and May when the roadway exhibits the greatest instability. Thus, the structural rating can vary from one year to the next depending upon the amount of moisture in the soil at the time of testing. For the most part, a high structural rating will correspond to a thicker overlay. Figure 2 shows the average annual structural ratings for each of the test sections. The

latest data indicated that Modified Mix No. 3 fared the best. The worst structural value seemed to be with the 152 mm (6 in) thick Mix No. 3 fly ash base.

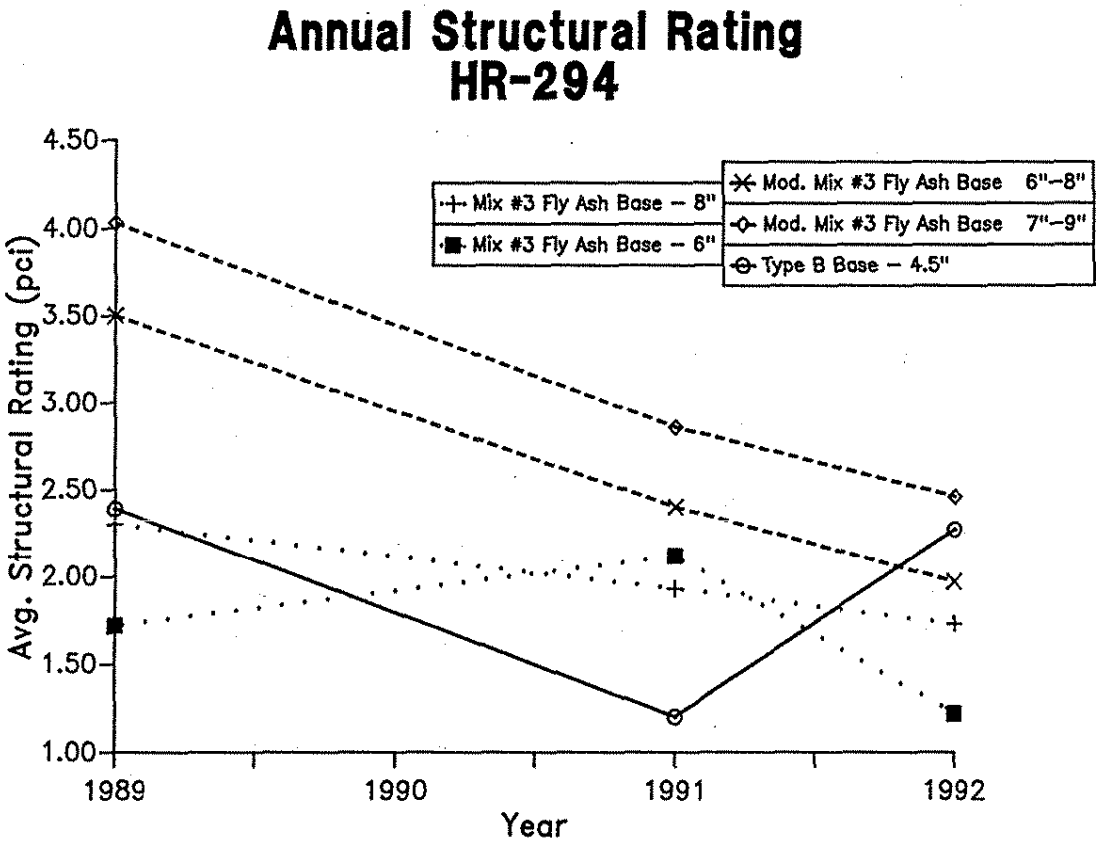


Figure 2

The Road Rater was also used to determine the structural rating of the fly ash base test sections prior to asphalt overlaying (Table III). This allowed an estimate for the structural layer coefficient to be determined. These initial structural layer

coefficients, especially of the Modified Mix No. 3 fly ash base, were slightly greater than the 0.44 limit give for such bases.

Sta. to Sta.	Structural Rating	Base Thickness (in)	Structural Layer Coeff.
110+00 114+50	3.59	7.5	0.48
115+00 122+50	3.42	7.2	0.48
123+00 124+00	3.13	7.2	0.43 *
125+00 128+50	4.02	7.5	0.54
1015+00 1021+50	2.75	7.8	0.34
1022+00 1030+50	1.95	8.3	0.23

* Uncompacted section

Table III - Road Rater Summary of Fly Ash Materials

CRACK SURVEY

A detailed crack survey of the pavement was conducted annually since the completion of the project in 1986. Figure 3 shows the comparisons between sections of total meters of cracks per road station. Quite obviously, surface cracking in the Type B base sections fared far better than any of the ammonium phosphate/fly ash base sections.

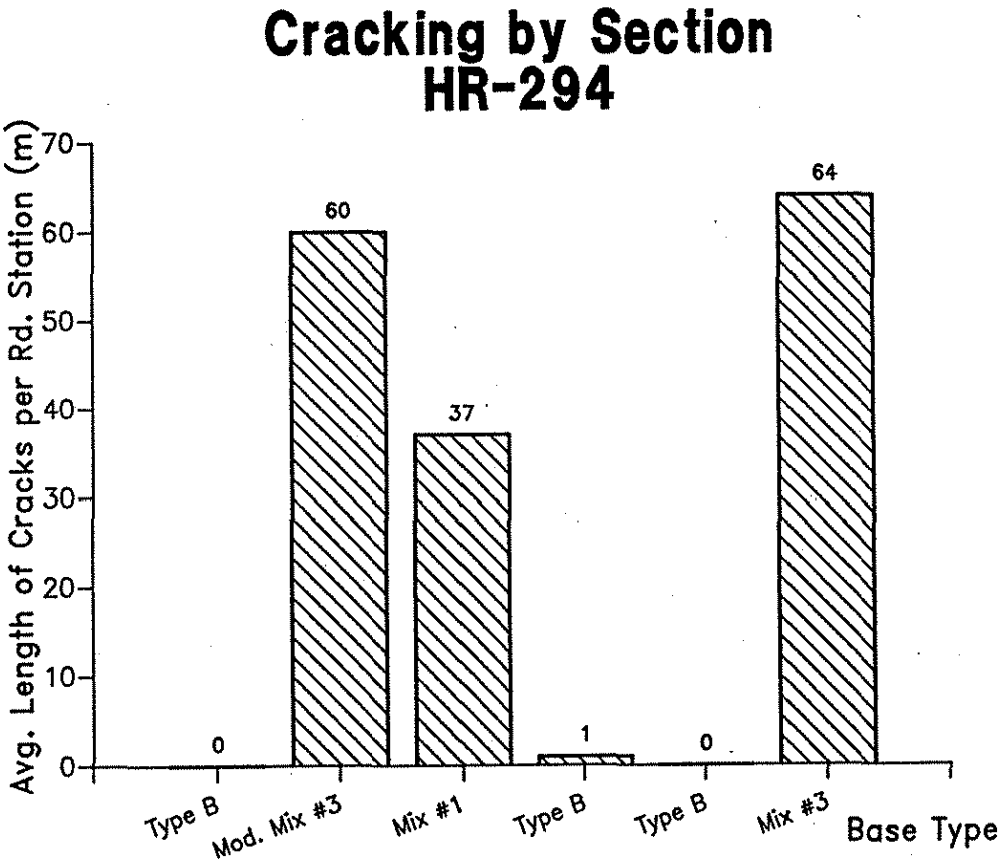


Figure 3

RUT DEPTH SURVEY

Rut depth measurements were taken in 1988 and 1993 in both the inside and outside wheelpaths. The results in Table IV do not indicate any significant differences between the research sections.

Base Material	Station to Station	Year	Avg. Rut Depth (in.)
Type B	101+00 to 109+00	1988	0.07
		1993	0.07
Mod. Mix #3	109+00 to 128+40	1988	0.05
		1993	0.10
Type B	132+00 to 152+18	1988	0.08
		1993	0.10
Type B	989+00 to 1014+70	1988	0.04
		1993	0.04
Mix #3	1014+70 to 1030+50	1988	0.05
		1993	0.06

Table IV - Rut Depth Measurements

COST

The breakdown of costs per ton for each mix is given in Figure 4. Although Mix No. 3 was considerably less expensive than the other mixes, this did not translate to better performance as witnessed by the amount of cracking in the surface course. In terms of maintenance costs, all the sections have needed substantial crack sealing except for the Type B base sections, which show little to no surface distress.

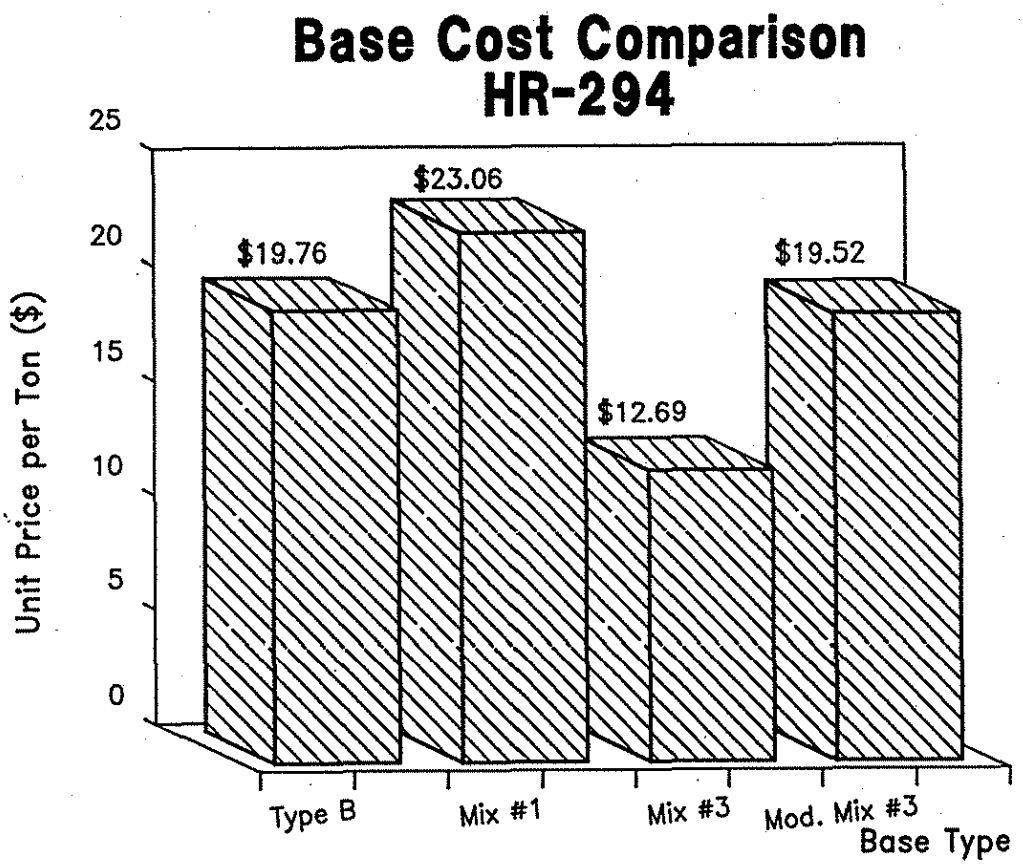


Figure 4

CONCLUSIONS

Some conclusions based upon performance of the research sections are as follows:

1. High structural ratings for the ammonium phosphate/fly ash base mixes did not translate to good roadway performance. All of these sections experienced moderate to severe cracking of the ACC pavement.

2. The Type B base sections have performed extremely well, with little or no surface distress to date.

3. Rut depth measurements for all research sections proved insignificant relative to one another.

4. The Type B base sections indicate lower overall life-cycle costs than the APFA base sections in terms of cost of mix and maintenance.

ACKNOWLEDGEMENT

The author wishes to extend appreciation to the Story County Board of Supervisors, Iowa State University and the Iowa DOT Highway Division for their support in developing and conducting this research. Thanks also go to Story County personnel for the extra effort put forth; Des Moines Asphalt & Paving Company and Manatt's Incorporated for their cooperation; and Vernon Marks, Kathy Davis and Steve Juhlin of the Iowa DOT Materials Research Office for their assistance in preparation of this report.

REFERENCES

1. Pitt, J.M., et al., (HR-294) Ammonium Phosphate/Fly Ash Road Base Construction, Construction Report, Iowa Department of Transportation, April 1987.

APPENDIX A
Project Contract

Form 740233 6-75 ACC Pavement

CONTRACT

Kind of Work w/Fly Ash Treated Base Miles 1.771

Project No. M-187, HR294 County Story

THIS AGREEMENT made and entered by and between Story County, Iowa, by its Board of Supervisors consisting of the following members: Fred L. Mathison, Donald E. Nelson and William G. Stucky, party of the first part, and Des Moines Asphalt & Paving Co. of Des Moines, Iowa, party of the second part.

WITNESSETH: That the party of the second part, for and in consideration of two hundred seventy one thousand five hundred twenty and 60/100 Dollars ($ 271,520.60) payable as set forth in the specifications constituting a part of this contract, hereby agrees to construct in accordance with the plans and specifications therefore, and in the locations designated in the notice to bidders, the various items of work as follows:

Item No.	Item	Quantity	Unit Price	Amount
1	Base, Type B, Class 2 Asphalt Cement Concrete	5,135 Tons	$ 19.76	$101,467.60
2	Asphalt Cement	325 Tons	$ 150.00	48,750.00
3	Sand, Load and Haul	1,100 Tons	$ 3.00	3,300.00
4	Limestone, 3/8"	2,100 Tons	$ 6.30	13,230.00
5	Fly Ash	1,350 Tons	$ 18.00	24,300.00
6	Ammonium Phosphate	10 Tons	$ 360.00	3,600.00
7	Base, Mix, Haul and Lay	5,050 Tons	$ 8.50	42,925.00
8	Primer or Sealer Bitumen	3,000 Gals.	$ 1.22	3,660.00
9	Binder Bitumen	2,000 Gals.	$ 1.15	2,300.00
10	Cover Aggregate, 3/8"	60 Tons	$ 25.73	1,543.80
11	Shoulder Construction, Earth	186.3 Stas.	$ 54.00	10,060.20
12	Seed, Fertilize and Mulch	2.2 Acres	$ 1,000.00	2,200.00
13	Traffic Control		Lump Sum	1,584.00
14	Samples		Lump Sum	500.00
15	Mobilization		Lump Sum	12,100.00
			TOTAL	$271,520.60

Said specifications and plans are hereby made a part of and the basis of this agreement, and a true copy of said plans and specifications are now on file in the office of the County Auditor under date of May 15, 19 86.

That in consideration of the foregoing, the party of the first part hereby agrees to pay to the party of the second part, promptly and according to the requirements of the specifications the amounts set forth, subject to the conditions as set forth in the specifications.

That it is mutually understood and agreed by the parties hereto that the notice to bidders, proposal, the specifications for Story County Project No. M-187, Story County, Iowa, the within contract, the contractor's bond, and the general and detailed plans are and constitute the basis of contract between the parties hereto.

That it is further understood and agreed by the parties of this contract that the above work shall be commenced on or before, and shall be completed on or before;

Approx. or Specified Starting Date or Number of Working Days	Specified Completion Date or Number of Working Days
30 Working Days	Sept. 19, 1986

That time is the essence of this contract and that said contract contains all of the terms and conditions agreed upon by the parties hereto.

It is further understood that the second party consents to the jurisdiction of the courts of Iowa to hear, determine and render judgement as to any controversy arising hereunder.

IN WITNESS WHEREOF the parties hereto have set their hands for the purposes herein expressed to this and three other instruments of like tenor, as of the 27th day of June, 19 86.

Approved: IOWA DEPARTMENT OF TRANSPORTATION

By _____ Contracts Engineer

Date JUL 01 1986

Story County, Iowa

Party of the first part

By _____ Chairman

DES MOINES ASPHALT & PAVING CO.

By _____

Party of the second part

APPENDIX B
1986 Special Provision For
Fly Ash Treated Base

STORY COUNTY, IOWA

SPECIAL PROVISION
for
FLY ASH TREATED BASE
Project M-187
Research Project HR 294
June 17, 1986

THE STANDARD SPECIFICATIONS OF THE IOWA DEPARTMENT OF TRANSPORTATION, SERIES OF 1984, SHALL APPLY TO THIS PROJECT EXCEPT AS AMENDED BY THE FOLLOWING ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

8586.01 GENERAL. This work consists of furnishing, mixing and placing a fly ash treated base, using a mixture of sand, crushed limestone, fly ash, ammonium phosphate and water. The mixture shall be prepared and placed according to the plans and this specification. Two thicknesses and a minimum of 2 different mixes are required.

This is a research project designed to provide important information concerning this type of base. The requirements of the plans and specifications may be modified to meet these research goals.

A conventional asphalt cement concrete base or seal coat is specified as a wearing course.

8586.02 MATERIALS. Sand for this base will be furnished by the County at no cost to the contractor. The contractor shall furnish all other materials. The materials shall be as follows:

A. Sand is to be a locally available sand. Preliminary tests show the following characteristics:

Sieve Size	% Passing
No. 4	100
No. 8	100
No. 16	99
No. 30	98
No. 50	77
No. 100	19
No. 200	2.4

The sand will be furnished by the County in its natural location at East Peterson Pit, at no cost to the contractor. The contractor shall load and haul the sand. Any material larger than 1 1/2" shall be removed from the sand.

B. Crushed Limestone - This is a locally available material commonly referred to as 3/8 minus. Preliminary tests show the following characteristics:

Sieve Size	% Passing
3/4"	100-90
1/2"	100-85
3/8"	95-80
#4	95-70
#8	75-40
#16	60-25
#30	50-20
#50	35-15
#100	25-10
#200	20-10

Any material larger than 1 1/2" shall be removed.

C. Fly ash shall be furnished by the contractor from sources approved by the engineer. Fly Ash shall be hydraulic, rapid setting, self cementing, such as that produced at currently approved, uncertified sources as follows:

Neal #4	Sioux City
Louisa	Grandview
Lansing	Lansing
Ames	Ames

D. Ammonmium Phosphate shall be Orthophosphate-Monohydrate (18-46-0) or Dia Ammonium Phosphate (18-46-0). The chemical composition shall be $(NH_4)_2 HPO_4$. The Ammonium Phosphate must be dissolved in water and added to the mix by being blended with the mix water.

E. Water. Section 4102 shall apply.

F. Sealer Bitumen. Shall be MC70.

G. Final Mixture. The final mixture shall be a combination of the following approximate quantities of individual materials based on dry weights.

Mix #1 - Limestone Fly Ash Base
- 3/8" minus - 1538 lbs.
- Fly Ash - 462 lbs.
- Ammonium Phosphate - 2.31 lbs.
- Water - 140 lbs.

Mix #2 - Sand-Limestone - Fly Ash Base
- 3/8" minus - 538 lbs.
- Sand - 1000 lbs.
- Fly Ash - 462 lbs.
- Ammonium Phosphate - 2.31 lbs.
- Water - 180 lbs.

The County reserves the right to alter these mix proportions based on field conditions. The amount of water used may be adjusted by the engineer.

8586.03 EQUIPMENT. Equipment to be used shall be as follows:

A. Proportioning and mixing shall be in a stationary plant. A conventional ACC plant as described in 2001.22, a conventional PCC plant as described in 2001.21 or another type of plant such as described in 2001.08 may be used subject to the approval of the Engineer. A stationary plant of another type will be considered for approval.

B. Placing Equipment shall be capable of placing the mixture to the full width and required thickness in one pass or be able to spread one-half the width and required thickness in one pass with the adjacent width being placed within one hour after the first pass is placed. Vibrating screeds and/or pan vibrators shall be available for use. If construction procedure leaves an exposed joint at centerline it shall be kept moist until the adjacent base is placed.

C. Compaction Equipment. Initial compaction shall be by a vibratory roller or compactor meeting requirements of 2001.05F. Based on field conditions, a tamping type roller meeting the requirements of 2001.05A may be required. Final compaction shall be by a steel- or rubber-tired roller meeting requirements of 2001.05B or C. If necessary, the weight of the compaction equipment will be adjusted in the field by the engineer.

D. Distributor. Article 2001.12 shall apply.

8586.04 SUBGRADE. The subgrade shall be prepared by the contractor in accord with 2109.04 and will not be measured for payment.

8586.05 CONSTRUCTION. The mixture shall be spread to the full width and full thickness in one operation or one-half width and full thickness with the remaining one-half width placed so the matching longitudinal joint will not be exposed for more than one hour. Any exposed longitudinal joint shall be kept moist. The thickness is to be varied as shown on the plans.

The mixture shall be compacted immediately after spreading. Compaction shall be to a target density of 100 percent of the density determined by compaction of samples of production mixture in a single, molded specimen in accord with AASHTO T 99, with a minimum density of 95 percent. The compaction and compaction procedure shall be based on maximum achievable compaction. An initial test section is contemplated. Compaction of the outside 1 foot may be minimized by the engineer and will not be subject to test. The engineer may modify or delete these compaction requirements. If a longitudinal joint is constructed compaction shall be carried out in such a manner as to not

destroy the vertical or near vertical condition of the base at the longitudinal joint.

An application of water may be necessary to facilitate compaction. A moist surface condition shall be maintained until the sealer bitumen is applied.

8586.06 SEALER BITUMEN. The completed base surface and edges shall be sealed at the rate of 0.2 gallon per square yard. The sealer shall be applied immediately after compaction of a section of base is completed. This may be done without the operation of equipment on the base. If field conditions are satisfactory the distributor may be allowed on the completed base with the axle load or capacity limited by the engineer.

8586.07 JOINTS. Some joints shall be sawn. Only those areas designated on the plans are to be sawn. Sawing of transverse joints shall be in accord with 2301.26 and 2301.27, skewed 6:1 at 15' and 20' intervals.

8586.08 ACC BASE. The contractor shall furnish and place a Type B ACC base on the completed fly ash base in accord with the plans and requirements of Section 2303. Placement of the full thickness in one lift is contemplated with Class I compaction. The full depth ACC Base shall be placed in accord with Section 2303.

8586.09 LIMITATIONS. The road will be partially closed to traffic during construction. The area from Sta. 110 to Sta. 132 will be closed. The area from Sta. 1007 to Sta. 1030+50 will be closed but adjacent residents must be allowed limited access. The remainder of the project will be marked "ROAD CLOSED - LOCAL TRAFFIC ONLY". Adjacent residents must be allowed access.

Except for sawing, there shall be no traffic or equipment operated on the completed base from the time the base is 3 hours old until it is 21 days old except as authorized by the Engineer. Hauling units which operate on the completed fly ash treated base shall be tandem axle, dual wheeled units. Loading may be restricted based on the strength of the cured base.

8586.10 SHOULDERS. The earth shoulders will be constructed by the contractor after the wearing course is placed. Shoulder material is available in East Peterson Pit. The contractor shall load and haul the material.

8586.11 METHOD OF MEASUREMENT. The various items involved in the construction of the fly ash treated base shall be measured as follows:

A. Sand. The quantity of sand used in the mix shall be measured by the ton when delivered to the mixing site.

B. Limestone. The quantity of 3/8" minus used in the mix shall be measured by the ton when delivered to the mixing site.

C. Fly Ash. The quantity of fly ash used in the mix shall be measured in tons when delivered to the mixing site.

D. Ammonium Phosphate. The quantity of ammonium phosphate used in the mix shall be measured in dry tons of material when delivered to the mixing site.

E. Alternate for Sand, Limestone and Fly Ash. If a batch plant is used the weights of these materials may be computed by counting batches in each truck and batch weights.

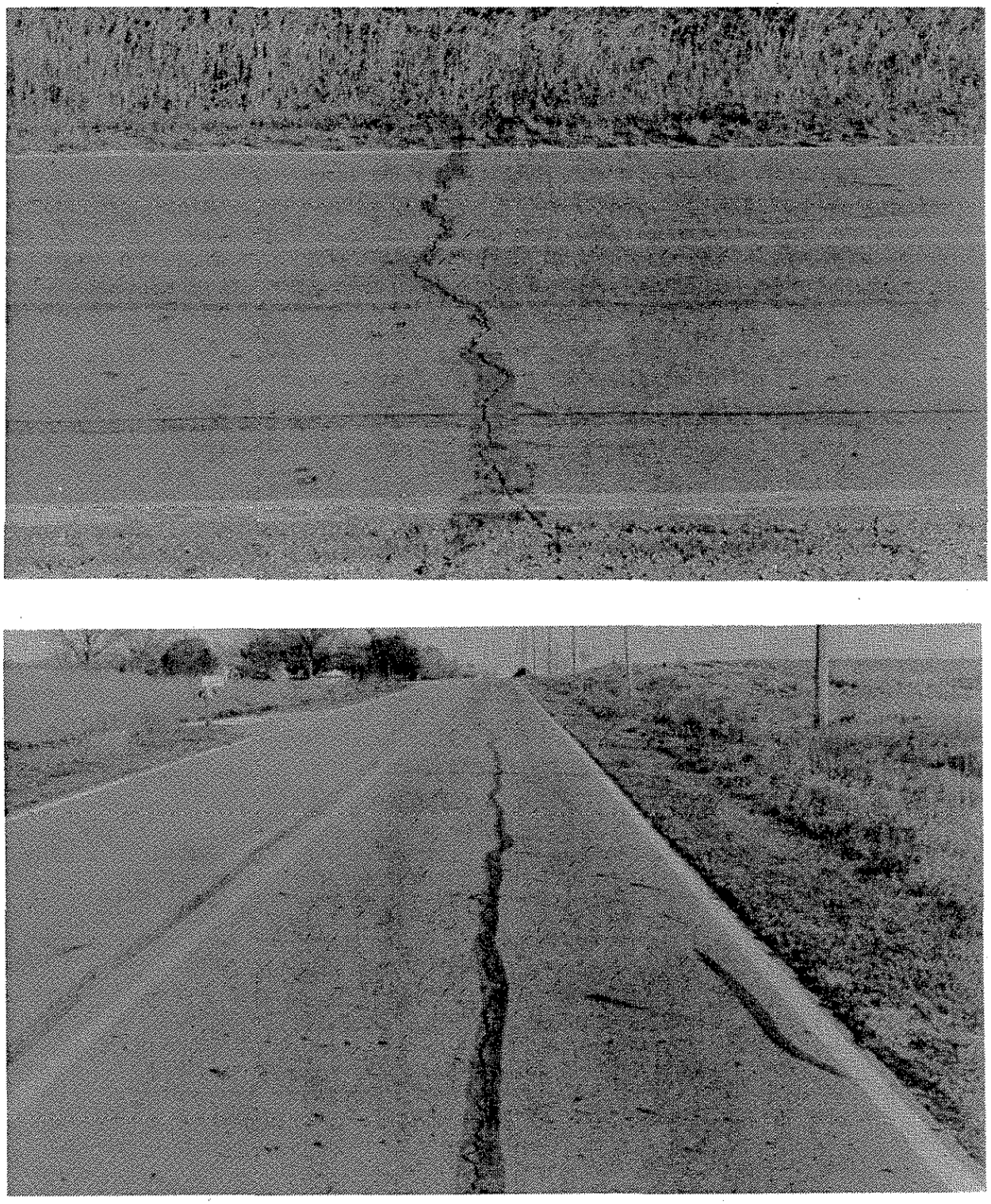
F. Base; Mix, Haul and Lay. Article 2303.27A(1) shall apply.

8586.12 BASIS OF PAYMENT.

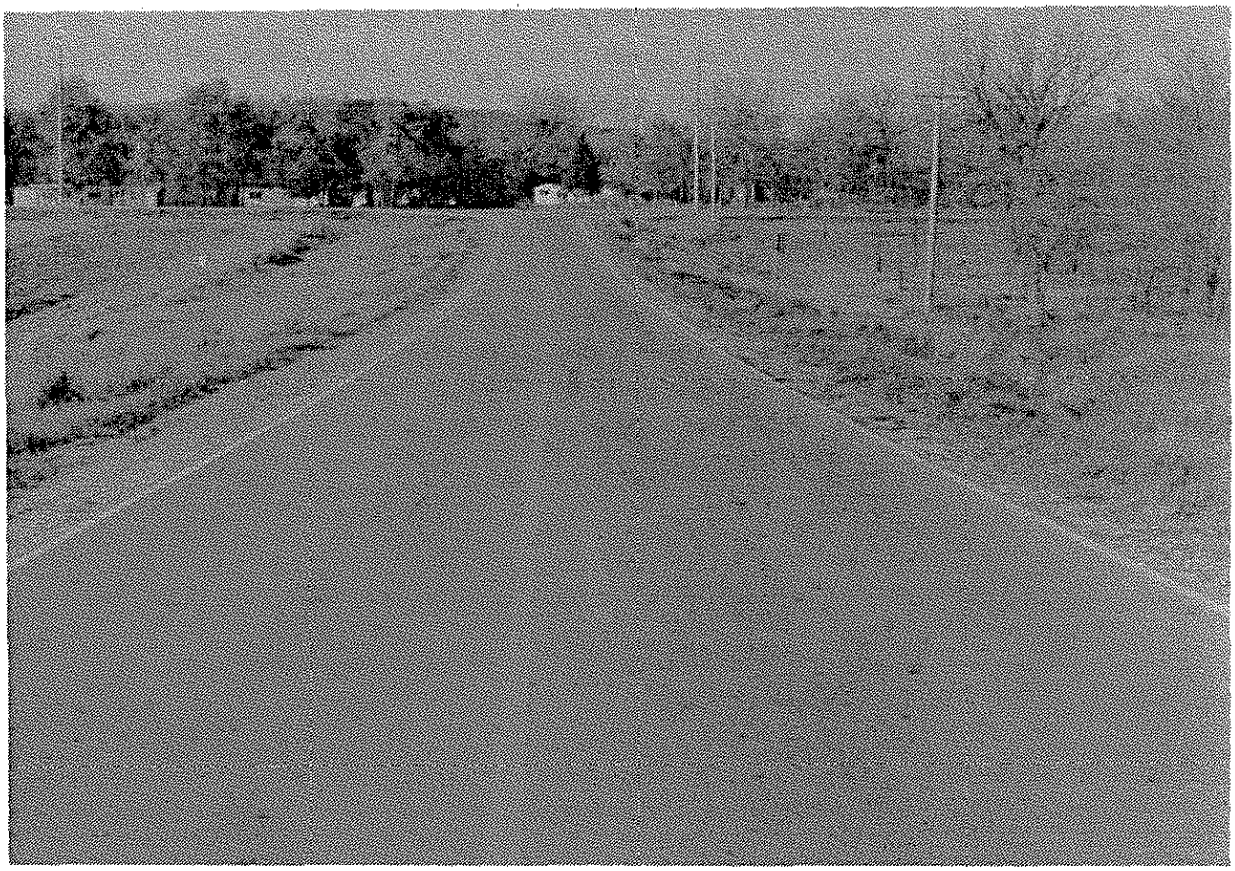
A. Sand, Limestone, Fly Ash, Ammonium Phosphate. For the number of tons of each measured for payment and used in the completed base the contractor will be paid the contract price per ton.

B. Base. Article 2303.28 shall apply.

APPENDIX C
Project Photographs



APFA Base Sections With Surface Cracks



Type B Base Section With No Surface Cracks